Lab team performs some of the largest direct numerical simulations of shocked turbulence

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The interaction of shock waves with turbulence is an important aspect in many types of flows, e.g., hypersonic flight, supersonic combustion, astrophysics, and Inertial Confinement Fusion (ICF). The Fluid Dynamics team in Computational Physics and Methods group has performed some of the largest direct numerical simulations of fluid turbulence in the world. The models enable investigation of specific physical phenomena that are typically inaccessible in experiments. The *Journal of Fluid Mechanics*, *Shock Waves*, and *Flow Turbulence Combustion* published the research.

Significance of the work

The interaction of a shock wave with turbulence represents a basic problem associated with high speed flows. This problem is very computationally challenging due to the large range of scales involved. The researchers have used direct numerical simulations (DNS) to elucidate the profound changes in the structure of post-shock turbulence, which has significant implications for turbulence modeling.

Turbulence theory relies on experiments and high resolution DNS for model development, verification, and validation. DNS is a powerful research tool that can be used to study the physics of turbulence, improve models, and guide the design of better experiments. The DNS technique provides accurate solutions of the governing equations, so that all relevant scales are accurately resolved.

Computations allow a degree of control in isolating specific physical phenomena that cannot be achieved in experiments. Advances in supercomputing technology and algorithms enable simulations of simple flows at ranges of scales comparable to or even larger than in laboratory experiments.

The simulations support DOE programs, including NNSA Defense Science and Advanced Simulation and Computing (ASC). The simulations provide accurate hydrodynamics simulations on advanced architectures and support future missions and capabilities for the national security mission.

Achievements

Researchers have used the results to calibrate the BHR (Besnard-Harlow-Rauenzahn) turbulence model at Mach numbers outside the reach of typical laboratory experiments. The team developed a two-length scale turbulence model to capture a wide variety of single-phase flows, from incompressible flows with single fluids, to mixtures of different density fluids (variable density flows), to flows over shock waves. The model focuses on separating the decay and transport length scales, because the two physical processes are generally different in inhomogeneous turbulence. This new model is a first step towards bridging the gap between homogenous and inhomogeneous flows.

The research team

Researchers include D. Livescu and J. R. Baltzer of Computational Physics and Methods, J. Ryu of the University of California-Berkeley, J. D. Schwarzkopf and R. A. Gore of XTD Integrated Design & Assessment and J. R. Ristorcelli of Methods & Algorithms.

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The graphic below shows that data generated in separate isotropic turbulence simulations are fed through the inlet of a shock tube with a stationary shock inside.